ORIGINAL CONTRIBUTION

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Digital volume tomography in the diagnosis of nasal bone fractures*

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SUMMARY

Digital volume tomography (DVT) is a kind of cone beam computed tomography and enables high quality 3D images of osseous structures. It is a well-established diagnostic tool in dentistry. High detail resolution is reached with a reduced exposition of radiation dose in comparison to conventional computed tomography. The data volume can be analysed in three orthogonal plains, which can be changed in angle arbitrarily. The aim of the study was to evaluate, if and in which performance DVT is able to detect discrete nasal bone fractures that cannot be seen in conventional radiography occasionally. DVT was performed in sixty-five patients with suspected nasal bone fracture. Five of these patients underwent lateral radiographs of the nasal bones in other departments which failed to show any radiologic signs of a nasal bone fracture, whereas DVT showed clear fracture lines. DVT-findings were also used to classify fractures according to their dimensions. Additionally DVT enabled the reconstruction of three-dimensional volume images. With this technique it is possible to get an image of the extent of the nasal bone fracture and the dislocation of the fragments. Because of these facts as well as its high resolution and low radiation dose, DVT can be recommended as the routine radiological examination in suspected nasal bone fractures.

Key words: Digital volume tomography (DVT), nasal bone fracture, cone beam tomography, rotational tomography, radiographic diagnosis

INTRODUCTION

Digital volume tomography (DVT) is a radiological alternative to plain radiographs and CT scans. This method is a further development of panoramic tomography and is characterised by high resolution, narrow sections of 0.125 mm width and a three-dimensional display in axial, coronal, and sagittal planes. Additional sections can be reconstructed arbitrarily in different angles to demonstrate the bony pathology in an optimal manner. Optionally three-dimensional reconstructions of the investigated volume can be calculated. The value of DVT as diagnostic tool for bony pathologies in dental surgery has been shown in several studies before [(1-3)].

In the meantime the value of DVT in the diagnosis of temporal bone pathologies could be demonstrated [(4,5)].

Fractures of the nasal bone are the most common fractures of ENT patients with trauma of the midface [(6)]. Some fractures that are verifiable by clinical examination and show no crepitation and/or dislocation from the midline cannot be detected by radiography, where a lateral image of the nasal bone or sometimes an occipito-mental radiograph is taken. As a consequence the usefulness of conventional radiography in cases of nasal bone fractures is doubted by some authors [(7)]. Because of radiation exposure and high costs, CT scan seems not to be an adequate solution in the diagnosis of nasal bone fractures, although some authors use high resolution CT scans to evaluate the dimensions of the nasal bone before a rhinoplasty is performed [(8)]. Nonetheless, radiological evidence of the nasal fracture is essential so as not to miss occult nasal bone fractures resulting in inadequate surgical treatment, which can lead to unsatisfying functional and aesthetic results. On the other hand it is important to document objectively nasal bone fractures because of the legal consequences resulting from the fractures causes. Additionally, nasal contusion can mimic nasal fracture by massive swelling of the soft tissue.

The aim of this study was to assess the diagnostic significance of DVT in the evaluation of nasal bone fractures, especially in

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fractures that cannot be detected by clinical signs or by lateral X-rays of the nasal bones.

PATIENTS AND METHODS

Digital volume tomography

Digital volume tomography (DVT) is a technique, which has been developed from panoramic tomography and was used in dental surgery first. The Accu-I-tomo (Morita, Kyoto, Japan) was used in the current study. The patient is examined sitting in an upright position on an adjustable chair. The head is fixed. The region of interest (ROI) is marked by target light beams that can be positioned arbitrarily (Figure 1). During examination the emitter-detector-unit rotates along the patient's head in 17.5 seconds. During this time 560 single slices of a section width of 0.125 mm are performed. The extension of the X-ray beam occurs in a conically shaped way: The top of the cone is the emitter of radiation; the base is the detector (Figure 2). The intersecting plain of the course of the beam is rectangular. A cylindrical volume (6 cm high and 6 cm in transverse diameter) is created by the rotation during examination. Since March 2008 a new generation of Accu-I-tomo was used. It features the opportunity to set the cylindrical volume at higher measures (8x8 cm, 10x10 cm and 12x17 cm addionally), so the nasal cavity, paranasal sinuses and the bony midface can be explored if necessary. The tube voltage is set at 80 kV, and the tube current was 8 mA. After calculating the ROI with special software (Idixel, Morita, Kyoto, Japan) and reconstruction of the images, slices can be displayed on a PC monitor in three plains, in a coronal, axial, and sagittal manner. The plains can be changed at will to demonstrate the best section angle to evaluate the pathology. It is possible to calculate three-dimensional reconstruction of the examined volume with display of bone and soft tissue in one image (Figure 3).

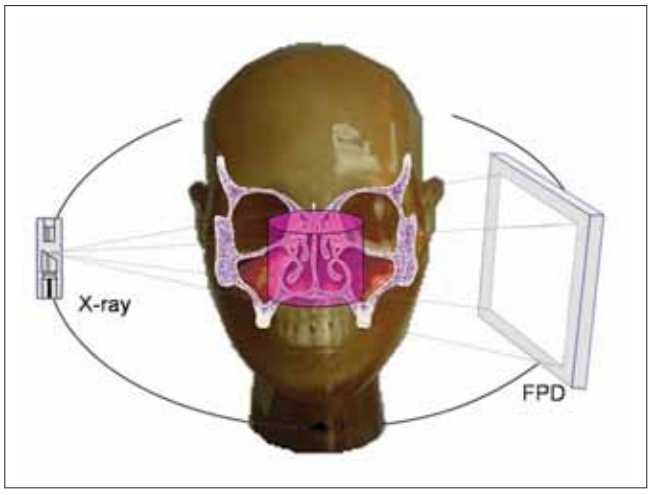

Figure 2. The extension of the X-ray beam occurs in a conically shaped way: The top of the cone is the emitter of radiation, the base is the detector. The intersecting plain of the course of the beam is rectangular. A cylindrical volume (6 cm high and 6 cm in transverse diameter(2^{nd} generation); upt to 12x17 cm in the 3^{rd} generation) is created by the rotation during examination.

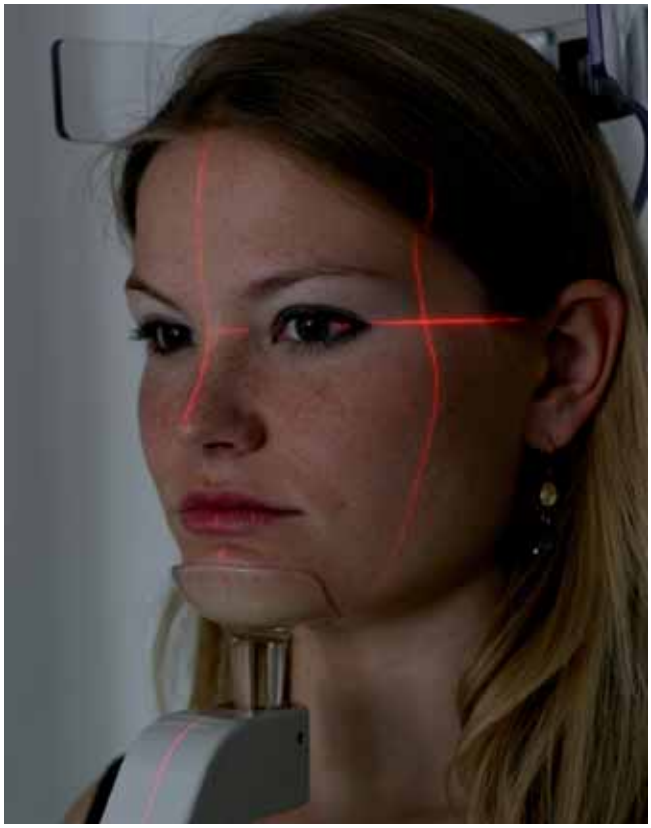

Figure 1. The ROI is marked with the target light beams.

Patients

Sixty-five patients (23 female, 37 male; mean age 33.5 years; range 12-94 years) with a detected nasal bone fracture were included in the study. Five patients underwent a conventional radiography but no fracture lines were found, despite strong suspicion of a nasal bone fracture, so additionally DVT scans were made. The radiographs were compared to the corre-

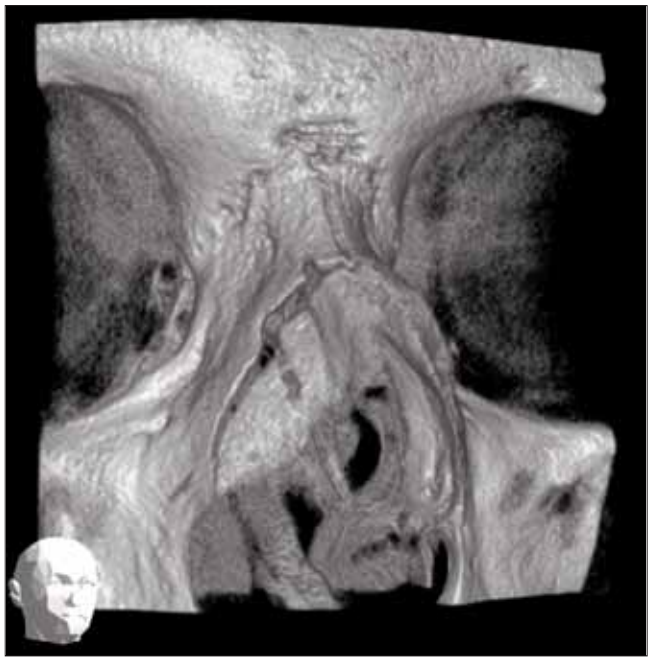

Figure 3. Reconstruction of the fracture shown in figures 5a-c.

Figure 4. Fracture of the anterior part of the nasal bones and displacement posteriorly.

sponding DVT slices to show a verifiable fracture. Three-dimensional reconstructions were made to complement the DVT images if necessary. The DVT scans were also used to grade the nasal bone fractures according to their dimensions. The study was carried out from April 2007 to April 2008.

RESULTS

In 65 patients fine fracture crevices and dislocated fragments could be verified by the high resolution and low rate of artefacts of the DVT images. In 40 cases (61%), the nasal trauma was caused by punches, 16 patients (24%) were injured by accidents. The other nasal traumas were caused by different injuries. The distribution of the fractures was as following: in 27 patients a nasal bone fracture without displacement was detected. The absence of displacement could be confirmed by three-dimensional reconstruction in cases of doubt. Eight patients had fractures of one lateral nasal wall with medial displacement of the fragments, whereas 10 patients had fractures of both lateral nasal walls with medial displacement. Seven patients suffered from a fracture of the anterior part of the nasal bone with posterior displacement (Figure 4). In 6 patients a fracture of the lateral and anterior parts of the nasal bone with posterior displacement could be detected. The nasal bone was crushed into several pieces with disappearance of the natural shape of the nose in 3 patients. Septal fracture in combination with any tape of nasal bone fracture was found in 4 patients (Figure 5 a-c). In these patients the septum was fractured in the cranial parts of the bony septum and the fracture was not evident in the clinical examination. The patients are summarised in Table 1.

Table 1. Summary of the nasal trauma, number and percentage.

Fracture character	n (%)
Nasal bone fracture without displacement of the fragments	27 (40)
Fracture of only one lateral nasal wall and displacement medially	8 (12)
Fracture of both lateral nasal walls and displacement medially	10 (15)
Fracture of the anterior part of the nasal bones and displacement posteriorly	7 (10)
Fracture of lateral and anterior parts of the nasal bones and displacement posteriorly	6 (9)
The nasal bone was crushed into several pieces and the natural shape has disappeared	3 (4)
Septal fracture was present with any type of nasal fracture	4 (6)

Comparing the five conventional radiographs with the corresponding DVT images provides objective evidence for fine fracture lines so a nasal bone fracture could be diagnosed in all of these patients. The findings were minor fractures with no or mild displacement of the nasal bone (Figure 6). By the detection of these fractures by DVT it succeeded to achieve correspondence of radiography and clinical signs in difficult cases.

In one patient with a severe nasal bone fracture with defects of the soft tissue of the nasal bridge additional midfacial fractures could be excluded by the use of the bigger cylindric volume

Figure 5. A: Septal fracture with any type of nasal fracture, coronar plane. B: axial plane. C: sagittal plane.

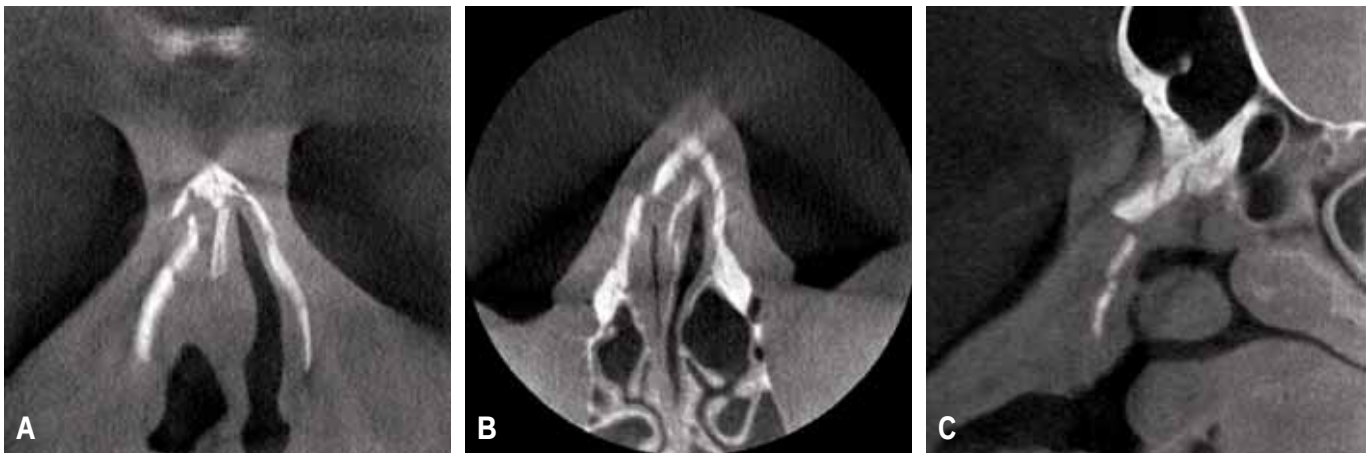

Figure 6. DVT shows the fracture of the nasal bone, whereas there is no assured visible fracture in the lateral image.

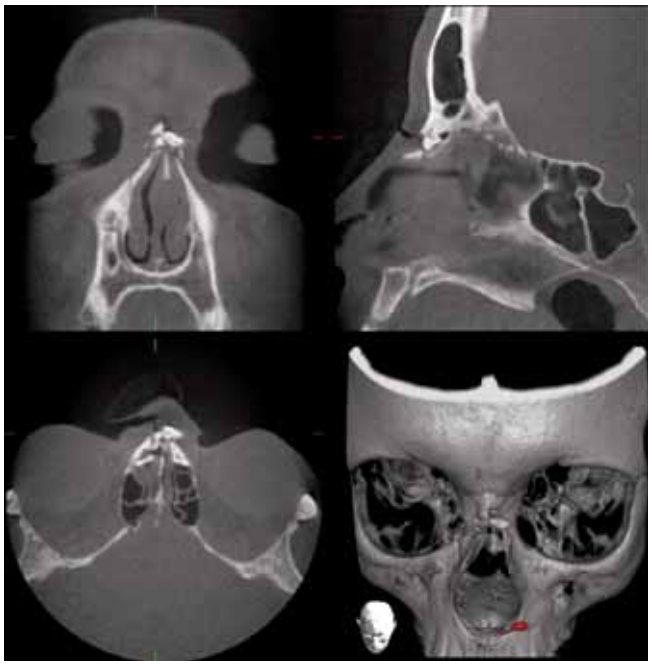

Figure 7. Patient with severe nasal trauma with a defect of the soft tissue, the 3D image demonstrates the extended dislocation of the fragments and shows a piercing which was covered during examination by a plaster.

(10 x 10 cm) of the new DVT device (Figure 7). By the use of the extended cylindric volume a CT scan of the midface was not necessary to exclude an additional blowout fracture or a fracture of the midface.

Reduction of the nasal fracture was performed in 56 patients (86%). This was done under local anaesthesia in 45 patients. In four patients general anaesthesia was used because of the necessary reconstruction of the septum, the other patients received general anaesthesia because of the fracture dimensions, incompliance or age under 15 years. Nine patients refused nasal reduction.

DISCUSSION

The oldest known description of nasal injuries and fractures is based on the Edwin Smith papyrus and is dated at about 1600 BC [9]. Fractures of the nasal bone are the most common isolated fractures of all facial injuries. Alvi and co-workers [6] found a frequency of 23 % in 151 patients who were presented in a trauma centre because of facial trauma. There are several types of classification of nasal bone fractures in the literature, starting in the early 20th century with Le Fort [10]. Other classifications were described by Kaznjian in 1933 [11], Lowenthal in 1953 [12] or Gollom [13], but a commonly accepted universal form of classifying nasal bone bone fractures does not exist in the literature.

Isolated nasal bone fractures are treated within 7 days after the injury by reduction of the nasal fracture under local anaesthesia in most cases. General anaesthesia can be necessary in incompliant patients or in children. In the case of non-treatment of a nasal bone fracture functional and/or aesthetic deficits such as nasal obstruction or deviation from the midline can result.

Conventional radiography using a lateral image is the gold standard in the radiologic display of nasal bone fractures, whereas some authors doubt the value of radiography in diagnosis of a nasal bone fracture. Nigam and co-workers [7] found a poor correlation between the radiological findings and the presence of external deformities so the authors conclude that routine radiography of the nose is unnecessary in patients with nasal trauma. A more precise imaging tool in cases of nasal trauma is computed tomography, but it has not been established as the method of choice because of high radiation dose and high costs. A useful alternative for the detection of nasal bone fractures could be digital volume tomography (DVT) because of its high resolution, ease of use and low radiation dose in comparison to conventional CT scans.

Digital volume tomography (DVT) is a relative new diagnostic tool for the evaluation of bony pathologies. The advantages are excellent detailed resolution superior to CT scan [14, 15], low radiation exposure, the images can be demonstrated with the common PC in three orthogonal plains, and a short examination time and the examined bone can be demonstrated in a three-dimensional reconstruction. A limitation for the establishment of this examination modality in the field of ENT is the small distribution, so far, because of it is a comparative novel development. In comparison to the Accu-I-tomo the acquisition of a new CT scanner is about two to five times more cost-intensive and an examination using DVT scans costs approximately the half of a CT scan.

DVT was first used in dental surgery for precise planning of dental implantation [15], especially in the evaluation of the course of the inferior alveolar nerve before surgical removal of third molars [11]. Mengel and co-workers [14, 15] compared CT and DVT in their studies on the diagnosis of periodontal defects and peri-implant defects in native pig and human mandibles. They found the best radiography images when using DVT scans. DVT showed also its value in operative diagnosis of patients with conductive hearing loss in a former study [4]. Findings of DVT scans were compared with the intraoperative situs. It was possible to confirm the preoperative findings intraoperatively concerning the continuity of the ossicular chain in all cases. The reason for better image quality is high resolution of DVT. The resolution in digital images is defined by the Voxel. CT reaches voxels with an edge length of 0.4 mm, voxels of DVT (Accu-I-tomo, Morita, Kyoto, Japan) have an edge length of down to 0.008 mm. The result is a better resolution of fine details [16, 17]. The product of dose and surface of DVT set at a tube voltage of 80 kV and tube current of 8 mA is 10 mGy/m^2 in comparison to 1400 mGy/m^2 of a conventional CT scan of the temporal bone. This low radiation exposure is caused by the use of cone beam technique. This means, the X-ray beams extend in conically shaped manner from the emitter to the detector and so the extent of irradiated tissue is reduced.

Conventional radiography is the widely accepted gold standard for nasal fractures even though there is only a sensitivity of 53 - 90% reported for the lateral image of the nasal bone [18]. As mentioned above, some authors even doubt the usefulness of conventional radiography in the diagnosis of nasal bone fracture because of its inaccuracy [7]. In their study Kwon and coworkers [19] showed that CT scan and ultrasound are superior to plain radiographs in the diagnosis of nasal fractures but radiation exposure and costs of CT scans are too high in relation to the additional information. Ultrasound is a reasonable alternative to CT scan and conventional radiography but there are also some disadvantages. It is a dynamic procedure that allows the investigator to make the diagnosis from an unlimited number of pictures. However, this fact makes it difficult to reproduce the pathologies from two or three printed images later [20]. Illum [18] points out the great importance of valid documentation of nasal bone fractures because of the high rate of criminal acts causing these lesions, especially in the cases in which a nasal bone fracture cannot be confirmed definitely with clinical means because of missing clinical signs such as crepitation or dislocation from the midline. Additional swelling of the outer nose can impede an adequate clinical examination. Another problem in the evaluation of nasal bone fractures are ambiguous findings in the lateral image of the nasal bone. In most of these patients DVT can give the missing information precisely. The current study was performed to check the ability of DVT to give clear information in these doubtful situations. For this aim 65 patients with a suspected nasal bone fracture underwent DVT during one year. In addition five of these patients received a conventional radiograph of the nose. In these five cases the image showed no fracture, but DVT was able to verify a nasal bone fracture in all patients. DVT showed the excellent potentials in the diagnosis of nasal bone fractures in this study in comparison to conventional radiography by showing a nasal bone fracture in three cases where plain radiography failed. Secondary an additional bony fracture of the nasal septum could be detected in four cases and adequate treatment could be performed. Using the options of the third generation of Accu-I-tomo, concomitant fractures of the midface could be excluded in one patient with severe nasal trauma. By analysing the DVT findings the surgeon can reach a very good understanding of the extent of the fracture and the dislocation of the fragments, especially when a three-dimensional reconstruction of the examined volume is used.

This study demonstrates the value of DVT for the detection of discrete nasal bone fractures. An advantage of DVT or CT scan compared to conventional radiography in cases of nasal fracture is the display and visualisation of the fracture. However, when CT is used, this advantage is at the cost of a high radiation exposure. This fact reduces the indication of CT scans to midfacial trauma. By the use of DVT excellent display and a superior image quality is achieved by low radiation exposure with the option of three-dimensional reconstruction. Confinement of DVT is the limited extent of the image by the defined cylindrical volume and also the big reduction of image quality in incompliant patients who are not able to hold the head fixed during the time of examination (17.5 seconds). In these relatively rare cases (extended midfacial trauma and incompliant patients, especially children) CT scan and/or plain radiography are the better options, but the indications for DVT may extend by the introduction of the new device generation.

CONCLUSION

DVT is a suitable imaging modality in the evaluation of nasal bone fractures. The capability of three-dimensional visualisation of the imaged fracture allows precise understanding of the fracture lines and the dislocation of the fragments. Additionally, DVT combines best image quality with low radiation exposure in short examination times. With the new DVT device generation the examiner has also the opportunity to display the whole nasal cavity, paranasal sinuses and the structures of the anterior skull base, so DVT can also used in cases of midfacial trauma in the future.

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